Technical Report Series on the
Boreal Ecosystem-Atmosphere Study (BOREAS)

G. Hall, Editor

Volume 84

BOREAS Level-0 ER-2 Daedalus TMS Imagery:
Scenes in PXL Format

J. Newcomer and R. Dominguez

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BOREAS Level-0 ER-2 Daedalus TMS Imagery: Digital Counts in BIL Format

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Available from:

BOREAS Level-0 ER-2 Daedalus TMS Imagery: Digital Counts in BIL Format

Jeffrey A. Newcomer, Roseanne Dominguez

Summary

The level-0 Daedalus TMS imagery, along with the other remotely sensed images, was collected to provide spatially extensive information about radiant energy over the primary BOREAS study areas. This information includes detailed land cover and biophysical parameter maps such as fPAR and LAI. Two flights of the Daedalus TMS instrument were made onboard the ER-2 aircraft on 16-Sep-1994 and 17-Sep-1994.

   Note that the level-0 Daedalus TMS data are not contained on the BOREAS CD-ROM set. An inventory listing file is supplied on the CD-ROM to inform users of the data that were collected. See Section 15 for information about how to acquire actual level-0 Daedalus TMS images.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification
   BOREAS Level-0 Daedalus TMS Imagery: Digital Counts in BIL Format

1.2 Data Set Introduction
   The BOReal Ecosystem-Atmosphere Study (BOREAS) Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of 12-band Daedalus Thematic Mapper Simulator (Daedalus TMS) image data collected on the National Aeronautics and Space Administration's (NASA's) ER-2 aircraft.

1.3 Objective/Purpose

For BOREAS, the Daedalus TMS imagery, along with the other remotely sensed images, was collected in order to provide spatially extensive information over the primary study areas. This information includes detailed land cover, biophysical parameter maps such as fraction of Photosynthetically Active Radiation (fPAR) and Leaf Area Index (LAI), and surface thermal properties.

1.4 Summary of Parameters

Daedalus TMS level-0 image data in the BOREAS Information System (BORIS) contain the following parameters: original housekeeping and calibration information and bands 1-12 in the NASA Ames Research Center (ARC) Band Interleaved by Line (BIL) format.

1.5 Discussion

BORIS staff processed the Daedalus TMS level-0 images by:
- Extracting pertinent header information from the level-0 image product and placing it in an American Standard Code for Information Interchange (ASCII) file on disk
- Reading the information in the disk file and loading the online data base with needed information

1.6 Related Data Sets

BOREAS Level-0 ER-2 Aerial Photography
BOREAS Level-0 AOCI Imagery: Digital Counts in BIL Format
BOREAS RSS-18 Level-1B AVIRIS Imagery: At-sensor Radiance in BIL Format

2. Investigator(s)

2.1 Investigator(s) Name and Title

BOREAS Staff Science

2.2 Title of Investigation

BOREAS Staff Science Aircraft Data Acquisition Program

2.3 Contact Information

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3. Theory of Measurements

The NASA Earth Resources Aircraft Program at Ames Research Center (ARC) operates the ER-2 aircraft to acquire data for Earth science research. The Daedalus TMS instrument used on the ER-2 aircraft collects radiance measurements in 10 spectral bands covering the visible and near-infrared spectrum from 0.436 to 1.054 micrometers (µm) and two thermal-infrared bands (one set in high gain and the other in low gain) covering 8.5 to 14.0 µm.

Thematic considerations have dictated, within technical constraints, the choice of spectral band position and width in the Daedalus TMS sensor. Twelve bands were selected, eight of which correspond to Landsat Thematic Mapper (TM) bands. These bands were chosen after many years of analysis for their value in discrimination of several Earth surface features. A blue (0.45 to 0.52 µm) band provides increased penetration of water bodies as well as supporting analyses of land use, soil, and vegetation characteristics. The lower-wavelength cutoff is just below the peak transmittance of clear water, while the upper-wavelength cutoff is the limit of blue chlorophyll absorption for healthy green vegetation. Wavelengths below 0.45 µm are substantially influenced by atmospheric scattering and absorption.

A green (0.52 to 0.60 µm) band spans the region between the blue and red chlorophyll absorption bands and therefore corresponds to the green reflectance of healthy vegetation. A red (0.63 to 0.69 µm) band includes the chlorophyll absorption band of healthy green vegetation and represents one of the most important bands for vegetation discrimination. The latter is also useful for soil and geological boundary delineations. A reflective-infrared (0.76 to 0.90 µm) band is especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil-crop and land-water contrasts.

One mid-infrared (1.55 to 1.75 µm) band is sensitive to the turgidity or amount of water in plants. Such information is useful in crop drought studies and in plant vigor investigations. In addition, these are two of the few bands that can be used to discriminate between clouds, snow, and ice, which is very important in hydrologic research. The other mid-infrared band (2.08 to 2.35 µm) is important for the discrimination of geologic rock formations. It has been shown to be particularly effective in identifying zones of hydrothermal alteration in rocks. Finally, the thermal-infrared (8.5 to 14.0 µm) band measures the amount of infrared radiant flux emitted from surfaces. The apparent temperature is a function of the emissivities and true or kinetic temperature of the surface. It is useful for locating geothermal activity, thermal inertia mapping for geologic investigations, vegetation classification, vegetation stress analysis, and soil moisture studies.

4. Equipment

4.1 Sensor/Instrument Description

The Daedalus TMS-1268 scanner is designed to simulate spectral, spatial, and radiometric characteristics of the TM sensor on the Landsat-4 and -5 spacecraft. The Daedalus TMS is generally flown at high altitudes aboard NASA's ER-2 aircraft based at ARC and provides 25-m resolution at nadir at an altitude of 19,800 m (65,000 ft).

The Daedalus TMS sensor differs slightly from the Landsat TM instruments. Its 12 spectral channels are very similar to those of the TM sensor, but it has an additional infrared channel. The 12 spectral channels of the Daedalus TMS sensor have the following bandpasses:

```
Daedalus TMS Channel      Wavelength, μm
-------------             --------------
   1                       0.42 - 0.45
   2  (TM1)                0.45 - 0.52
   3  (TM2)                0.52 - 0.60
   4                       0.60 - 0.62
   5  (TM3)                0.63 - 0.69
   6                       0.69 - 0.75
   7  (TM4)                0.76 - 0.90
   8                       0.91 - 1.05
   9  (TM5)                1.55 - 1.75
  10  (TM7)                2.08 - 2.35
  11  (TM6)  (high gain)   8.5  - 14.0
  12  (TM6)  (low gain)    8.5  - 14.0
```

4.1.1 Collection Environment
As part of the BOREAS Staff Science Data Collection Program, BORIS distributed 12-band level-0 Daedalus TMS image data. The Daedalus TMS was flown on NASA's ER-2 aircraft during the BOREAS mission (see the BOREAS Experiment Plan for flight pattern details and objectives). Maintenance and operation of the instrument are the responsibility of ARC. The ER-2 Experimenter's Handbook (supplemental) produced by the High Altitude Missions Branch at ARC provides a description of the instrument, calibration procedures, and data format.

4.1.2 Source/Platform
NASA's ER-2 Earth Resources Aircraft.

4.1.3 Source/Platform Mission Objectives
The original purpose of the Daedalus TMS was to provide high-altitude data in the visible, near-infrared, and thermal-infrared regions of the electromagnetic spectrum for use in land surface remote sensing and comparing with the Landsat TM instrument.

4.1.4 Key Variables
Emitted radiation, reflected radiation, and temperature.

4.1.5 Principles of Operation
None given.

4.1.6 Sensor/Instrument Measurement Geometry
```
Instantaneous Field-Of-View (IFOV)        1.25 mrad
Total Scan Angle                          42.5 degrees
Pixels/Scan Line                          716
```

Sensor footprint is 25.0 m x 25.0 m at nadir at 19,800 m altitude.

4.1.7 Manufacturer of Sensor/Instrument
Daedalus Enterprises
Ann Arbor, Michigan

4.2 Calibration

4.2.1 Specifications
The wavelength ranges (in µm) of the bands for the Daedalus TMS are:

```
Daedalus TMS Channel            Wavelength, µm
-------------------             --------------

    1                           0.42 - 0.45
    2  (TM1)                    0.45 - 0.52
    3  (TM2)                    0.52 - 0.60
    4                           0.60 - 0.62
    5  (TM3)                    0.63 - 0.69
    6                           0.69 - 0.75
    7  (TM4)                    0.76 - 0.90
    8                           0.91 - 1.05
    9  (TM5)                    1.55 - 1.75
   10  (TM7)                    2.08 - 2.35
   11  (TM6)  (high gain)       8.5  - 14.0
   12  (TM6)  (low gain)        8.5  - 14.0


DESIGN DATA:
IFOV                            1.25 milliradians
Across-track FOV                +/- 21.25 degrees
Inflight calibration            Integrating sphere and two
                                  controllable blackbodies

Short wavelength array temperature  255 K
V/H range                       Variable 0.025 to 0.25
Scan rate                       Variable 10 to 100 scans/sec.
Scan speed ability              One-third of the IFOV, scan
                                  line to scan line

Data quantization               8 bits (256 discrete levels)
                                  for all bands

Number of video samples/scan line  716
Roll compensation               +/-15 degrees
Scan mirror                     45-degree rotating mirror
```

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibration
The ARC Sensor Calibration Laboratory measures the Spectral Response Function (SRF) of each band several times per year using a full-aperture scanning monochromator. Radiometric calibration is regularly performed using a 30-in. integrating sphere with a 12-in. exit aperture. The sphere is calibrated periodically against a National Institute of Standards and Technology (NIST) standard reference source. The SRF is then convolved with the measured sphere radiance to produce in-band radiance for bands 1-10. The thermal IR bands (11 and 12) are calibrated with the two onboard blackbody reference sources that are viewed before and after each scan line during the data acquisition, together with the SRF measured in the laboratory.

4.2.3 Other Calibration Information
Daedalus TMS data may be intentionally overscanned, e.g., operated at some integral multiple of the desired scan rate and then subsampled in preprocessing. The subsampling factor is reported as a "demagnification factor."

5. Data Acquisition Methods

As part of the BOREAS Staff Science Data Collection Program, BORIS distributed 12-band level-0 Daedalus TMS image data. The Daedalus TMS was flown on NASA's ER-2 aircraft during the BOREAS Mission (see the BOREAS Experiment Plan for flight pattern details and objectives). Maintenance and operation of the instrument are the responsibility of ARC. The ER-2 Experimenter's Handbook (supplemental) produced by the High Altitude Missions Branch at ARC provides a description of the instrument, calibration procedures, and data format.

6. Observations

6.1 Data Notes
None given.

6.2 Field Notes
None given.

7. Data Description

7.1 Spatial Characteristics
The BOREAS level-0 Daedalus TMS images cover the Southern Study Area (SSA) and the Northern Study Area (NSA), which are located in the southwest and northeast portions of the overall BOREAS region.

7.1.1 Spatial Coverage
The North American Datum of 1983 (NAD83) corner coordinates of the SSA are:

	Latitude	Longitude
Northwest	54.321 N	106.228 W
Northeast	54.225 N	104.237 W
Southwest	53.515 N	106.321 W
Southeast	53.420 N	104.368 W

The NAD83 corner coordinates of the NSA are:

	Latitude	Longitude
Northwest	56.249 N	98.825 W
Northeast	56.083 N	97.234 W
Southwest	55.542 N	99.045 W
Southeast	55.379 N	97.489 W

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The Daedalus TMS IFOV provides a footprint of 25.0 m at nadir at an altitude of 19,800 m, which was typical of the BOREAS flight.

7.1.4 Projection
The level-0 Daedalus TMS images were not placed in any sort of map or geographic coordinate projection.

7.1.5 Grid Description
The BOREAS level-0 Daedalus TMS images are stored in their original data collection frame with increasing pixel sizes from nadir to the scanning extremes based on the scan angle.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
The level-0 Daedalus TMS image data were collected on 16-Sep-1994 and 17-Sep-1994.

7.2.2 Temporal Coverage Map
```
Study Area    Dates
----------    ---------------------
SSA           16-Sep-1994 NSA 17-Sep-1994
```

7.2.3 Temporal Resolution
Images were acquired only on 16-Sep-1994 and 17-Sep-1994.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameter contained in the image data files is: `Digital Number (DN)`

The parameters contained in the inventory listing file on the CD-ROM are:
```
        Column Name
------------------------------
SPATIAL_COVERAGE
DATE_OBS
START_TIME
END_TIME
PLATFORM
INSTRUMENT
NUM_BANDS
PLATFORM_ALTITUDE
MIN_SOLAR_ZEN_ANG
MAX_SOLAR_ZEN_ANG
MIN_SOLAR_AZ_ANG
MAX_SOLAR_AZ_ANG
ER2_MISSION_ID
BAND_QUALITY
CLOUD_COVER
DTMS_MEAN_FRAME_STATUS
NW_LATITUDE
NW_LONGITUDE
NE_LATITUDE
NE_LONGITUDE
SW_LATITUDE
SW_LONGITUDE
SE_LATITUDE
SE_LONGITUDE
CRTFCN_CODE
```

7.3.2 Variable Description/Definition
For the image data files:
```
Digital Number (DN) - The quantized DN derived by the Daedalus TMS scanning
                      system for the respective channel.
```

The descriptions of the parameters contained in the inventory listing file on the CD-ROM are:

```
         Column Name                        Description
------------------------------   --------------------------------------------------
SPATIAL_COVERAGE                 The general term used to denote the spatial area
                                 over which the data were collected.
DATE_OBS                         The date on which the data were collected.
START_TIME                       The starting Greenwich Mean Time (GMT) for the
                                 data collected.
END_TIME                         The ending Greenwich Mean Time (GMT) for the
                                 data collected.
PLATFORM                         The object (e.g., satellite, aircraft, tower,
                                 person) that supported the instrument.
INSTRUMENT                       The name of the device used to make the
                                 measurements.
NUM_BANDS                        The number of spectral bands in the data.
PLATFORM_ALTITUDE                The nominal altitude of the data collection
                                 platform above the target.
MIN_SOLAR_ZEN_ANG                The minimum angle from the surface normal
                                 (straight up) to the sun during the data
                                 collection.
MAX_SOLAR_ZEN_ANG                The maximum angle from the surface normal
                                 (straight up) to the sun during the data
                                 collection.
MIN_SOLAR_AZ_ANG                 The minimum azimuthal direction of the sun
                                 during data collection expressed in clockwise
                                 increments from North.
MAX_SOLAR_AZ_ANG                 The maximum azimuthal direction of the sun
                                 during data collection expressed in clockwise
                                 increments from North.
ER2_MISSION_ID                   The mission identifier assigned to the ER2
                                 mission in the form of YY-DDD where YY is the last
                                 two digits of the fiscal year, and DDD is the
                                 deployment number. An example would be 94-120.
BAND_QUALITY                     The data analyst's assessment of the quality of
                                 the spectral bands in the data.
CLOUD_COVER                      The data analyst's assessment of the cloud cover
                                 that exists in the data.
DTMS_MEAN_FRAME_STATUS           The mean frame status calculated from the
                                 respective values on the digital tape of AOCI data
                                 collected during the given flight.
NW_LATITUDE                      The NAD83 based latitude coordinate of the
                                 north west corner of the minimum bounding
                                 rectangle for the data.
NW_LONGITUDE                     The NAD83 based longitude coordinate of the
                                 northwest corner of the minimum bounding rectangle
                                 for the data.
NE_LATITUDE                      The NAD83 based latitude coordinate of the
                                 northeast corner of the minimum bounding rectangle
```

```
                                       for the data.
NE_LONGITUDE                           The NAD83 based longitude coordinate of the
                                       northeast corner of the minimum bounding rectangle
                                       for the data.
SW_LATITUDE                            The NAD83 based latitude coordinate of the
                                       southwest corner of the minimum bounding rectangle
                                       for the data.
SW_LONGITUDE                           The NAD83 based longitude coordinate of the
                                       southwest corner of the minimum bounding rectangle
                                       for the data.
SE_LATITUDE                            The NAD83 based latitude coordinate of the
                                       southeast corner of the minimum bounding rectangle
                                       for the data.
SE_LONGITUDE                           The NAD83 based longitude coordinate of the
                                       southeast corner of the minimum bounding rectangle
                                       for the data.
CRTFCN_CODE                            The BOREAS certification level of the data.
                                       Examples are CPI (Checked by PI), CGR (Certified
                                       by Group), PRE (Preliminary), and CPI-??? (CPI but
                                       questionable).
```

7.3.3 Unit of Measurement

For the image data files: `Digital Number (DN) - counts`

The measurement units for the parameters contained in the inventory listing file on the CD-ROM are:

```
        Column Name                        Units
--------------------------------   --------------------------------------------------
SPATIAL_COVERAGE                   [none]
DATE_OBS                           [DD-MON-YY]
START_TIME                         [HHMM GMT]
END_TIME                           [HHMM GMT]
PLATFORM                           [none]
INSTRUMENT                         [none]
NUM_BANDS                          [counts]
PLATFORM_ALTITUDE                  [meters]
MIN_SOLAR_ZEN_ANG                  [degrees]
MAX_SOLAR_ZEN_ANG                  [degrees]
MIN_SOLAR_AZ_ANG                   [degrees]
MAX_SOLAR_AZ_ANG                   [degrees]
ER2_MISSION_ID                     [none]
BAND_QUALITY                       [none]
CLOUD_COVER                        [none]
DTMS_MEAN_FRAME_STATUS             [unitless]
NW_LATITUDE                        [degrees]
NW_LONGITUDE                       [degrees]
NE_LATITUDE                        [degrees]
NE_LONGITUDE                       [degrees]
SW_LATITUDE                        [degrees]
SW_LONGITUDE                       [degrees]
SE_LATITUDE                        [degrees]
SE_LONGITUDE                       [degrees]
CRTFCN_CODE                        [none]
```

7.3.4 Data Source

The level-0 AOCI image bands were collected by the Daedalus TMS instrument on the ER2 aircraft. The raw data were decommutated, processed, and sent to BORIS by personnel within the High Altitude Aircraft Branch at NASA ARC. The source of the parameter values contained in the inventory listing file on the CD-ROM are:

```
       Column Name                      Data Source
-------------------------------  --------------------------------------------------

SPATIAL_COVERAGE                 [ER2 Flight Summary Reports and calculations
                                 within the BORIS software using information from
                                 the Daedalus TMS image data]
DATE_OBS                         [DTMS image housekeeping data]
START_TIME                       [DTMS image housekeeping data
END_TIME                         [DTMS image housekeeping data]
PLATFORM                         [Constant software parameter value]
INSTRUMENT                       [Constant software parameter value]
NUM_BANDS                        [Constant software parameter value]
PLATFORM_ALTITUDE                [ER2 Flight Summary Reports]
MIN_SOLAR_ZEN_ANG                [Calculated from DATE_OBS, TIME_OBS, and
                                 latitude and longitude information]
MAX_SOLAR_ZEN_ANG                [Calculated from DATE_OBS, TIME_OBS, and
                                 latitude and longitude information]
MIN_SOLAR_AZ_ANG                 [Calculated from DATE_OBS, TIME_OBS, and
                                 latitude and longitude information]
MAX_SOLAR_AZ_ANG                 [Calculated from DATE_OBS, TIME_OBS, and
                                 latitude and longitude information]
ER2_MISSION_ID                   [ER2 Flight Summary Reports]
BAND_QUALITY                     [Constant software parameter value]
CLOUD_COVER                      [Constant software parameter value]
DTMS_MEAN_FRAME_STATUS           [Calculated with software from the DTMS image
                                 housekeeping data]
NW_LATITUDE                      [Calculated from the nadir latitude and longitude,
                                 heading, and altitude information in the Flight
                                 Summary Report, the constant instrument scan
                                 angle, and mean aircraft roll angle calculated
                                 from the image housekeeping data]
NW_LONGITUDE                     [Calculated from the nadir latitude and longitude,
                                 heading, and altitude information in the Flight
                                 Summary Report, the constant instrument scan
                                 angle, and mean aircraft roll angle calculated
                                 from the image housekeeping data]
NE_LATITUDE                      [Calculated from the nadir latitude and longitude,
                                 heading, and altitude information in the Flight
                                 Summary Report, the constant instrument scan
                                 angle, and mean aircraft roll angle calculated
                                 from the image housekeeping data]
NE_LONGITUDE                     [Calculated from the nadir latitude and longitude,
                                 heading, and altitude information in the Flight
                                 Summary Report, the constant instrument scan
                                 angle, and mean aircraft roll angle calculated
                                 from the image housekeeping data]
SW_LATITUDE                      [Calculated from the nadir latitude and longitude,
                                 heading, and altitude information in the Flight
                                 Summary Report, the constant instrument scan
```

```
                                        angle, and mean aircraft roll angle calculated
                                        from the image housekeeping data]
        SW_LONGITUDE                    [Calculated from the nadir latitude and longitude,
                                        heading, and altitude information in the Flight
                                        Summary Report, the constant instrument scan
                                        angle, and mean aircraft roll angle calculated
                                        from the image housekeeping data]
        SE_LATITUDE                     [Calculated from the nadir latitude and longitude,
                                        heading, and altitude information in the Flight
                                        Summary Report, the constant instrument scan
                                        angle, and mean aircraft roll angle calculated
                                        from the image housekeeping data]
        SE_LONGITUDE                    [Calculated from the nadir latitude and longitude,
                                        heading, and altitude information in the Flight
                                        Summary Report, the constant instrument scan
                                        angle, and mean aircraft roll angle calculated
                                        from the image housekeeping data]
        CRTFCN_CODE                     [Constant data base value]
```

7.3.5 Data Range

The maximum range of DNs in each level-0 Daedalus TMS image band is limited from 0 to 255 8 bits and is stored in an 8 bit (byte) field. The following table gives information about the parameter values found in the inventory table on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SPATIAL_COVERAGE	N/A	N/A	None	None	None	None
DATE_OBS	16-SEP-94	17-SEP-94	None	None	None	None
START_TIME	1525	1917	None	None	None	None
END_TIME	1528	1919	None	None	None	None
PLATFORM	ER2	ER2	None	None	None	None
INSTRUMENT	N/A	N/A	None	None	None	None
NUM_BANDS	12	12	None	None	None	None
PLATFORM_ALTITUDE	19294	20117	None	None	None	None
MIN_SOLAR_ZEN_ANG	67.4	70.7	None	None	None	None
MAX_SOLAR_ZEN_ANG	67.7	71	None	None	None	None
MIN_SOLAR_AZ_ANG	278.2	282.5	None	None	None	None
MAX_SOLAR_AZ_ANG	278.7	283	None	None	None	None
ER2_MISSION_ID	94-142	94-143	None	None	None	None
BAND_QUALITY	N/A	N/A	None	None	None	None
CLOUD_COVER	N/A	N/A	None	None	None	None
DTMS_MEAN_FRAME_ STATUS	0	0	None	None	None	None
NW_LATITUDE	53.30309	56.11041	None	None	None	None
NW_LONGITUDE	-106.37569	-98.07578	None	None	None	None
NE_LATITUDE	53.29144	56.07513	None	None	None	None
NE_LONGITUDE	-106.05544	-97.73023	None	None	None	None
SW_LATITUDE	53.04724	55.78351	None	None	None	None
SW_LONGITUDE	-106.45527	-98.17967	None	None	None	None
SE_LATITUDE	53.03523	55.75309	None	None	None	None
SE_LONGITUDE	-106.14049	-97.83677	None	None	None	None
CRTFCN_CODE	PRE	PRE	None	None	None	None

```
--------------------------------------------------------------------------
Minimum Data Value  -- The minimum value found in the column.
Maximum Data Value  -- The maximum value found in the column.
Missng Data Value   -- The value that indicates missing data. This is used to
                       indicate that an attempt was made to determine the
                       parameter value, but the attempt was unsuccessful.
Unrel Data Value    -- The value that indicates unreliable data.  This is used
                       to indicate an attempt was made to determine the
                       parameter value, but the value was deemed to be
                       unreliable by the analysis personnel.
Below Detect Limit  -- The value that indicates parameter values below the
                       instruments detection limits.  This is used to
                       indicate that an attempt was made to determine the
                       parameter value, but the analysis personnel determined
                       that the parameter value was below the detection
                       limit of the instrumentation.
Data Not Cllctd     -- This value indicates that no attempt was made to
                       determine the parameter value.  This usually
                       indicates that BORIS combined several similar but
                       not identical data sets into the same data base table
                       but this particular science team did not
                       measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
--------------------------------------------------------------------------
```

7.4 Sample Data Record

A sample data record for the level-0 Daedalus TMS images is not available here. The following are wrapped versions of the first few records from the level-0 Daedalus TMS inventory table on the CD-ROM:

```
SPATIAL_COVERAGE,DATE_OBS,START_TIME,END_TIME,PLATFORM,INSTRUMENT,NUM_BANDS,
PLATFORM_ALTITUDE,MIN_SOLAR_ZEN_ANG,MAX_SOLAR_ZEN_ANG,MIN_SOLAR_AZ_ANG,
MAX_SOLAR_AZ_ANG,ER2_MISSION_ID,BAND_QUALITY,CLOUD_COVER,DTMS_MEAN_FRAME_STATUS,
NW_LATITUDE,NW_LONGITUDE,NE_LATITUDE,NE_LONGITUDE,SW_LATITUDE,SW_LONGITUDE,
SE_LATITUDE,SE_LONGITUDE,CRTFCN_CODE
'SSA',16-SEP-94,1638,1641,'ER2','DTMS',12,19355.0,68.0,68.3,278.9,279.2,'94-142',
'NOT ASSESSED','NOT ASSESSED',0,53.35978,-105.81133,53.34787,-105.55107,53.12695,
-105.84026,53.11511,-105.58145,'PRE'
'SSA',16-SEP-94,1647,1653,'ER2','DTMS',12,19538.0,68.7,69.2,279.7,280.4,'94-142',
'NOT ASSESSED','NOT ASSESSED',0,54.22481,-104.62804,54.20971,-104.35274,
53.7896,4,-104.69562,53.7747,-104.4232,'PRE'
```

8. Data Organization

8.1 Data Granularity
The smallest unit of level-0 Daedalus TMS data is a single flight line of data. Although the image inventory is contained on the BOREAS CD-ROM set, the actual level-0 DTMS images are not. See Section 15 for information about how to obtain the data.

8.2 Data Format(s)
A level-0 Daedalus TMS tape contains one header file followed by up to 50 files containing data from Daedalus TMS flight lines. The header file contains one record of 9,192 bytes that contain a mixture of ASCII and binary values. The multibyte integer fields are stored as high-order byte first. The contents of the header record fields are:

```
    Bytes                          Description
 ---------    -------------------------------------------------------------
   1 -  80    Data Description (ASCII characters, e.g., 'TMS (BOREAS) Canada')
  81 -  90    Flight Number (ASCII characters, e.g., 94-143)
  91 - 120    Data Collection Date (ASCII characters, e.g., 16 SEPTEMBER 1994)
 121 - 150    Data Decommutation Date (ASCII characters)
 151 - 180    Archive Tape Creation Date (ASCII characters)
 181 - 182    Aircraft Number (binary 16-bit integer, value of 708)
 183 - 184    Scanner Type (ASCII characters)
 185 - 186    Reel Number (binary 16-bit integer)
 187 - 188    Expected Number of Reels (binary 16-bit integer)
 189 - 198    Filler bytes
 199 - 200    Number of Channels Processed (binary 16-bit integer)
 201 - 224    Channel Numbers (binary 16-bit integers)
 225 - 236    Filler bytes
 237 - 238    Mode used to specify flight line boundaries (ASCII characters)
              (AL = all data contained in one flight line)
              (SL = selected scan lines) (BOREAS tape)
              (GM = selected times)
 239 - 240    Number of Operator-specified flight line intervals
              (binary 16-bit integer)
 241 - 244    Start of flight line interval number 1 (binary 32-bit integer)
 245 - 248    Start of flight line interval number 2 (binary 32-bit integer)
      .
      .
 437 - 440    Start of flight line interval number 50 (binary 32-bit integer)
 441 - 444    End of flight line interval number 1 (binary 32-bit integer)
 445 - 448    End of flight line interval number 2 (binary 32-bit integer)
      .
      .
 637 - 640    End of flight line interval number 50 (binary 32-bit integer)
 641 - 9192   Filler bytes
```

Each level-0 Daedalus TMS image from a given flight is contained in one tape file. A physical tape record of 9,192 bytes contains 12 logical records of 766 bytes that contain housekeeping information (50 bytes) and the image data (716 bytes) from the 12 Daedalus TMS spectral bands in BIL order. The bytes of the 16-bit and 32-bit values in the housekeeping information are ordered as high-order byte first. The detailed structure of each logical record is:

```
Daedalus TMS Logical Data Record Structure

   Bytes 1 - 50  Housekeeping Information
      1 - 2       Data Frame Status (16-bit integer)
                  0 implies the data are good; nonzero implies they are bad.
                  10 Interpolated data
                  20 Repeated data
                  30 Zero fill data
      3 - 4       Run Number (16-bit integer)
      5 - 8       Scan line count (32-bit integer)
      9 - 12      Panel Thumbwheel switches (32-bit integer)
                  Consists of 8 digits in the form YYFFFJJJ
                  where YY is the last two digits of the year (e.g., 94)
                       FFF is the flight number (e.g., 120)
                       JJJ is the day of the year (e.g., 202)
     13 - 14      Blackbody #1 Thermal Reference Temperature (16-bit integer)
                  (hundredths of degrees C)
     15 - 16      Blackbody #2 Thermal Reference Temperature (16-bit integer)
                  (hundredths of degrees C)
     17 - 18      Scan Speed (16-bit integer) (tenths of scans per second)
     19 - 20      Greenwich Mean Time (GMT) hours (16-bit integer)
     21 - 22      Minutes of the hour (16-bit integer)
     23 - 24      Tenths of seconds (16-bit integer)
     25 - 26      Demagnification value * 100 (16-bit integer)
                  (Set to 100 to indicate unity, i.e., no demagnification)
     27 - 28      Filler (16-bit integer)
     29 - 30      Gain Value (times 1000) (16-bit integer)
     31 - 32      Channel Number (16-bit integer)
     33 - 36      Time (32-bit integer)
                  (7 digits in the form of hhmmsst where hh is the hour,
                  mm is the minutes, ss is the seconds, and t is the tenths
                  of a second)
     37 - 38      Blackbody #1 Response (16-bit integer) (Counts)
                  (What the sensor sees when it looks at Blackbody #1)
     39 - 40      Blackbody #2 Response (16-bit integer) (Counts)
                  (What the sensor sees when it looks at Blackbody #2)
     41 - 42      Aircraft Roll angle counts (16-bit integer)
                  (0.03 degrees per count or 0.06 degrees per pixel)
                  (Positive values indicate rotation of the aircraft in a
                  clockwise direction when viewed from the front;
                  negative values indicate counterclockwise rotation)
     43 - 50      Filler bytes
Bytes 51 - 766 Binary Image data
     51 - 766     Digital counts for pixels 1 to 716 of the scan line (8-bit)
```

The CD-ROM inventory listing file consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

9. Data Manipulations

9.1 Formulae
None.

9.1.1 Derivation Techniques and Algorithms
None.

9.2 Data Processing Sequence

9.2.1 Processing Steps
BORIS staff processed the level-0 Daedalus TMS imagery by:
- Creating duplicate copies of the original image data tapes
- Extracting information from the tape to ASCII files on disk
- Using the extracted ASCII disk file information to inventory the images by date and location in the online data base

9.2.2 Processing Changes
None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
None given.

9.3.2 Calculated Variables
None.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
None given.

10.2 Quality Assessment

10.2.1 Data Validation by Source
Spectral errors could arise because of image-wide signal-to-noise ratio, saturation, cross-talk, spikes, or response normalization caused by a change in gain.

10.2.2 Confidence Level/Accuracy Judgment
None given.

10.2.3 Measurement Error for Parameters
None given.

10.2.4 Additional Quality Assessments
None given.

10.2.5 Data Verification by Data Center
BORIS staff reviewed the Daedalus TMS images through software that summarized the housekeeping information in the records of each flight line and histogrammed the image bands to gather minimum, maximum, mean, and standard deviation values, which were then reviewed before loading the information into the data base. No anomalous values were noted.

11. Notes

11.1 Limitations of the Data
Not available at this revision.

11.2 Known Problems with the Data
To date, no discrepancies or problems have been noted in the data.

11.3 Usage Guidance
Not available at this revision.

11.4 Other Relevant Information
None given.

12. Application of the Data Set

This data set can be used to supplement Landsat TM or other high-resolution satellite images for land cover analyses.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description
BORIS staff developed software and command procedures for:
- Extracting header information from level-0 Daedalus TMS images on tape and writing it to ASCII files on disk
- Reading the ASCII disk file and logging the level-0 Daedalus TMS image products into the Oracle data base tables

14.2 Software Access
The software is written in C and is operational on VAX 6410 and MicroVAX 3100 systems at Goddard Space Flight Center (GSFC). The primary dependencies in the software are the tape input/output (I/O) library and the Oracle data base utility routines.

15. Data Access

The level-0 Daedalus TMS imagery is available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information
For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification
Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data
Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans
The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
The BOREAS level-0 Daedalus TMS data can be made available on 1600 or 6250 Bytes Per Inch (BPI) Digital Archive Tape (DAT), 9-track, or 8-mm tapes.

16.2 Film Products
None.

16.3 Other Products
Although the image inventory is contained on the BOREAS CD-ROM set, the actual level-0 DTMS images are not. See Section 15 for information about how to obtain the data.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Airborne Instrumentation Research Project - Flight Summary Report Series. 1994. NASA Ames Research Center, Airborne Missions and Applications Division, Moffett Field, California. 94035.

NASA. 1990. ER-2 Earth Resources Aircraft Experimenter's Handbook. National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California.

17.2 Journal Articles and Study Reports

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102 (D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation
    None.

18. Glossary of Terms

None given.

19. List of Acronyms

```
AOCI    - Airborne Ocean Color Imager
ARC     - Ames Research Center
ASCII   - American Standard Code for Information Interchange
AVIRIS  - Airborne Visible and Infrared Imaging Spectrometer
BIL     - Band Interleaved by Line
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BPI     - Bytes Per Inch
CCT     - Computer Compatible Tape
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
DAT     - Digital Archive Tape
DN      - Digital Number
DTMS    - Daedalus Thematic Mapper Simulator
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
fPAR    - fraction of Photosynthetically Active Radiation
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
IFOV    - Instantaneous Field-of-View
I/O     - Input/Output
LAI     - Leaf Area Index
NAD     - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NIST    - National Institute of Standards and Technology
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
RSS     - Remote Sensing Science
SRF     - Spectral Response Function
SSA     - Southern Study Area
TM      - Thematic Mapper
μm      - micrometers
URL     - Uniform Resource Locator
```

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13. ABSTRACT (Maximum 200 words)

The level-0 Daedalus TMS imagery, along with the other remotely sensed images, was collected to provide spatially extensive information about radiant energy over the primary BOREAS study areas. This information includes detailed land cover and biophysical parameter maps such as fPAR and LAI. Two flights of the Daedalus TMS instrument were made onboard the ER-2 aircraft on 16-Sep-1994 and 17-Sep-1994.

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